

DESIGN AND DEVELOPMENT OF PNEUMATIC COTTON BOLL PICKING MACHINE

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ABSTRACT

This paper focuses on design and development of a new machine, to pick cotton bolls. In India, entire cotton is handpicked by labour, and internationally available machines for picking the cotton bolls are costlier and not affordable to Indian farmers. Also, these machines are not suitable for Indian farming condition. Pneumatic cotton boll picking machine, will give a new technology in the field of agriculture which is helpful for Indian farmers.

KEY WORDS: Cotton Boll Picking Machine, CFD Analysis, Impeller & Tetrahedron Elements

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INTRODUCTION

In the world, China and India are the largest producers of cotton. Cotton is an important commercial crop in India. In India, the state of Maharashtra, Gujarat, Andhra Pradesh and Madhya Pradesh are leading cotton producing states, where cotton is harvested manually. A cotton boll picking machine, that plucks the cotton from the boll without damaging the cotton plants, does not exist in India. The average land holding capacity of farmers is 1-3 hectares of land. Hence, pneumatic cotton-picking machine will be very useful for Indian farmers, for minimizing drudgery involving in hand picking.

A pneumatic type cotton boll picking machine has been designed and developed, to pluck cotton from cotton boll, by using pure suction method. When engine gets started, impeller starts rotating and suction is created at the outlet. By using this suction pressure, cotton can be picked from cotton boll, with the help of hose pipe. Pneumatic cotton boll picking machine, has been designed ergonomically, having low weight and very efficient for Indian farms. It is a knapsack type machine. The proposed machine is affordable and easy to handle. Farmers can easily use pneumatic cotton-picking machine, without fatigue.

Main Components

Table 1: Main Components

Name of Component	Figure	Dimension	Material	Weight
Frame		10 mm diameter	Mild Steel	2.2 Kg
Tank		600mm length and 150mm diameter	Plastic	0.8 kg
Impeller		Inner diameter 70mm Outer diameter 240mm.	Fiber casing with steel blade.	1.8kg
Two Stroke IC Engine		Rallis L-35/HPO Bore-35mm Stroke-36mm P= 1.34KW	`	4.2Kg
Spark Plug		Mico W17521Type		0.1Kg
Pipe		30 * 300 mm and 50* 1000 mm (Diameter × length)		0.1kg
Total Weight of Machine				9.2kg

DESIGN CALCULATIONS

The pneumatic force required to pluck a normal cotton boll is 3.5N, with discharge of 0.025 m³/s (velocity =12.73 m/s). A standard 1.34 KW powered two strokes IC- Engine, with 500 rpm has been used, which have been connected with impeller to produce the required force, to pluck cotton boll from cotton.

Design of Shaft (D_s)

Motor Power = $P = 1.34$ KW.

Speed = $N = 500$ r.p.m.

$$\text{Power } P = \frac{2\pi NT}{60} \times K_L$$

Where, K_L -Load factor = 1.15; T -Torque

$$T = 19.606 \text{ N-m}$$

Considering material SAE 1030 and factor of safety is 3.

$$\text{Permissible shear stress} = \tau = 61 \text{ N/mm}^2$$

$$T = \frac{\pi}{16} \tau D_s^3$$

$$D_s = 11.78 \text{ mm.}$$

Increasing the diameter by 50%

$$D_s = 17.67 \text{ mm.}$$

Standardizing diameter of Shaft = 20 mm [7]

Design of Impeller

The diameter of the impeller eye, D_o , depends on the shaft diameter, D_s . The hub diameter, D_H , is made 5/16 to 1/2 inch larger than D_s . After estimating D_s and D_H , D_o is based on the known flow rate. To ensure smooth flow, the inlet vane diameter D_1 , has made about the same as D_o . D_2 is outlet vane diameter.

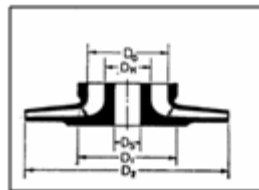


Figure 1: Cross Section of Impeller

$$D_H = \frac{5}{16} D_s + D_s$$

$$D_H = \frac{5}{16} 20 + 20$$

$$D_H = 26.25 \text{ mm}$$

Considering hub diameter = 28mm.

Selected impeller discharge is $0.04 \text{ m}^3/\text{s}$, and the required discharge is $0.25 \text{ m}^3/\text{s}$, with velocity of 12.73 m/s .

$$V_{su} = V_o = 12.73 \text{ m/s}$$

$$Q = V_{su} D_s u^2 / 4$$

$$D_s u^2 = 50 \text{ mm}$$

Since, required suction pipe diameter is 50mm.

$$Q = V_o \left(\frac{\pi D_o^2}{4} - \frac{\pi D_H^2}{4} \right)$$

$$D_o = 68.49 \text{ mm} = D_1$$

Since inlet diameter of impeller is 70mm (Standard Diameter).[7]

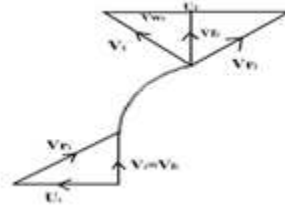


Figure 2: Velocity Diagram

$$U_1 = \frac{\pi D_1 N}{60}$$

$$U_1 = \frac{3.14 \times 70 \times 500}{60 \times 1000}$$

$$U_1 = 18.32 \text{ m/s}$$

Inlet angle is usually $10^\circ - 25^\circ$.

As per the impeller vane blade, inlet angle θ is

$$\theta = 13^\circ \text{ (vane angle at inlet)}$$

$$\tan \theta = \frac{V_{f1}}{U_1}$$

$$V_{f1} = 18.80 \text{ m/s}$$

Width of the Impeller,

$$b_1 = \frac{Q}{\pi \epsilon V_{f1} D_1}$$

Where $\epsilon = 0.85$

$$b_1 = 50.62 \text{ mm}$$

From inlet velocity triangle

$$V_{r1} = 18.80 \text{ m/s}$$

Outlet Diameter of Impeller is 240mm

$$U_2 = \frac{\pi D_2 N}{60}$$

$$U_2 = 62.8 \text{ m/s}$$

The normal range of discharge angle is $20^\circ - 25^\circ$.

$\phi = 20^\circ$ (outlet angle of impeller).

$$V_{f1} - V_{f2} = 4.229 \text{ m/s.}$$

$$\tan \theta = \frac{V_{f2}}{U_2 - V_{w2}}$$

$$V_{w2} = 51.18 \text{ m/s.}$$

$$\tan \beta = \frac{V_{f2}}{V_{w2}}$$

$$\beta = 4.72^\circ$$

$$V_{r2} = \sqrt{\{(U_2 - V_{w2})^2 + V_{f2}^2\}}$$

$$V_{r2} = 12.36 \text{ m/s}$$

Pressure Calculation

Pressure created by impeller at the outlet.

$$P = 249.08 * 1.1 \left(\frac{N * D * 39.37}{153 * 10^4} \right)^2$$

$$P = 2612.41 \text{ Pa.}$$

Now,

$$P = \rho g H$$

Where,

$$H = 225.10 \text{ m}$$

$$V = \sqrt{2 * 9.81 * H}$$

$$V = 66.45 \text{ m/s}$$

Velocity at the outlet of impeller is 66.45 m/s.

Pressure difference,

$$\Delta P = P_2 - P_1$$

$$\Delta P = -98732.59 \text{ N/m}^2$$

$$\text{Pressure Ratio} = P_2 / P_1$$

$$= 0.025577.$$

This pressure difference is sufficient to pluck cotton from cotton boll.

Hose Pipe Design

Pipe diameter from impeller to the tank, D_{pipe} :

$$Q = AV$$

$$0.04 = \frac{\pi}{4} D_{\text{pipe}}^2 \times 66.45$$

$$D_{\text{pipe}} = 29.37 \cong 30 \text{ mm}$$

Velocity inside the pipe

$$Q = AV$$

Where,

A-Cross-sectional area of pipe and V- velocity of flow through pipe

$$0.04 = \frac{\pi}{4} D_{\text{pipe}}^2 \times V$$

$$V = 56.617 \text{ m/s.}$$

Head loss due to friction

$$H_1 = \frac{4fL}{2gD_{\text{pipe}}} V^2$$

Where,

f - Coefficient of friction; L- Length of pipe; V- Velocity inside the pipe

$$Re = \frac{VD_{\text{pipe}}}{\nu}$$

Re - Renold's Number.

ν - Kinematic viscosity of air

$$Re = \frac{56.617 \times 0.3}{15.98 \times 10^{-6}}$$

$$Re = 1.24579 \times 10^5$$

Coefficient of friction

$$f = \frac{0.0791}{Re^{1/4}} = 0.004208$$

$$H_1 = \frac{4 \times 0.004208 \times 0.3 \times 56.617^2}{2 \times 9.81 \times 0.03} = 0.12$$

Velocity of flow inside the tank.

$$A_1 V_1 = A_2 V_2$$

$$V_2 = 2.26 \text{ m/s}$$

Now,

Velocity at suction pipe

$$A_2 V_2 = A_3 V_3$$

$$V_3 = 20.34 \text{ m/s}$$

As required velocity is 12.73 m/s and calculated velocity, at suction pipe outlet is 20.34 m/s. So, with the velocity available at suction pipe outlet, it is possible to pluck cotton from cotton boll.

CFD ANALYSIS

The CFD analysis has been carried out using Ansys13.Workbench Software. The process involved following steps

- Design of blade model as per input parameter.
- The model is meshed using tetrahedron elements of size 2mm. The mesh is fined at areas near to the blade thus, providing a fine boundary layer for simulation. The meshed domain is the fluid domain.
- Creating of the solver setup in which, the model of the fluid domain was divided into regions of inlet & outlet surfaces.
- Determining parameters, that needed as input pressure, pressure ratio, density etc.

Using this procedure, CFD Analysis of impeller has been carried out, and velocity and pressure on blade has been calculated. There are 18 blades and flow system, that has been considered as an axial inlet and radial outlet type.

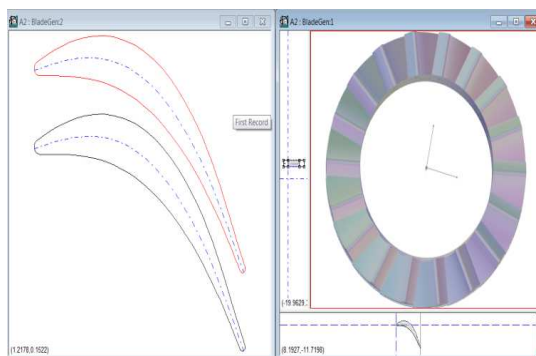


Figure 3: Blade Design

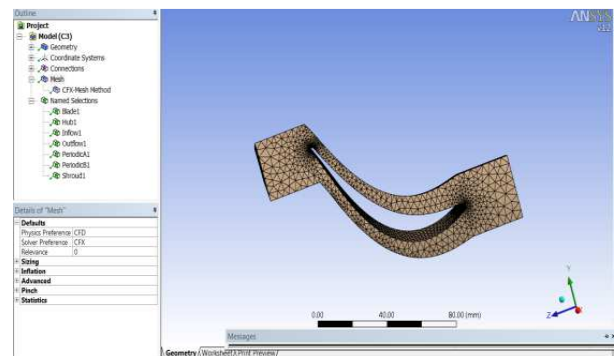


Figure 4: Meshing of Blade

Analysis was considered as Steady State Analysis. Fluid domain was considered as air with the given settings, as the above EPISILON turbulence model, used for turbulence modeling.

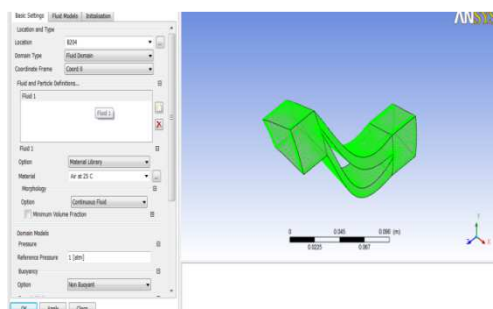


Figure 5: Flow of Fluid

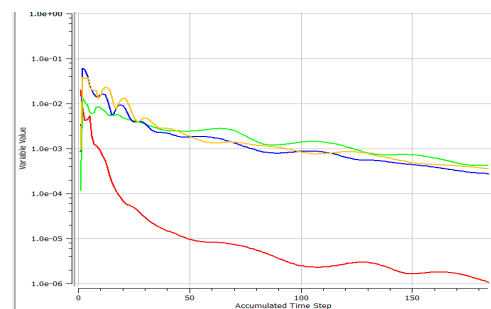


Figure 6: Iteration Graph

Convergence criteria have been considered as 0.001, for both the pressure and velocity. The results are obtained by taking 190 iterations, till the model shows the required criteria that is needed.

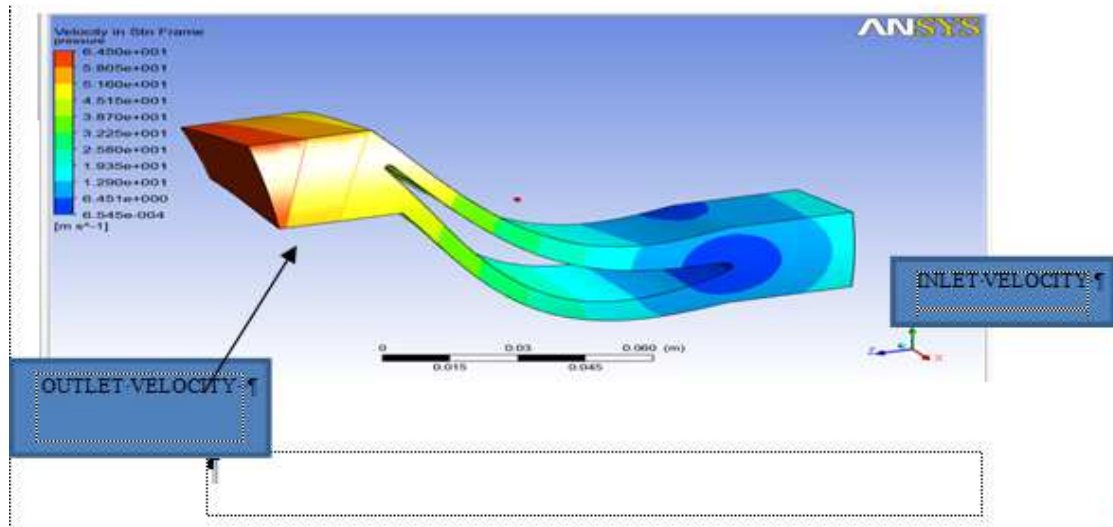


Figure 7: Stagnant Velocity at Inlet and Outlet

The velocity at the outlet was found to be 64.50 m/s.

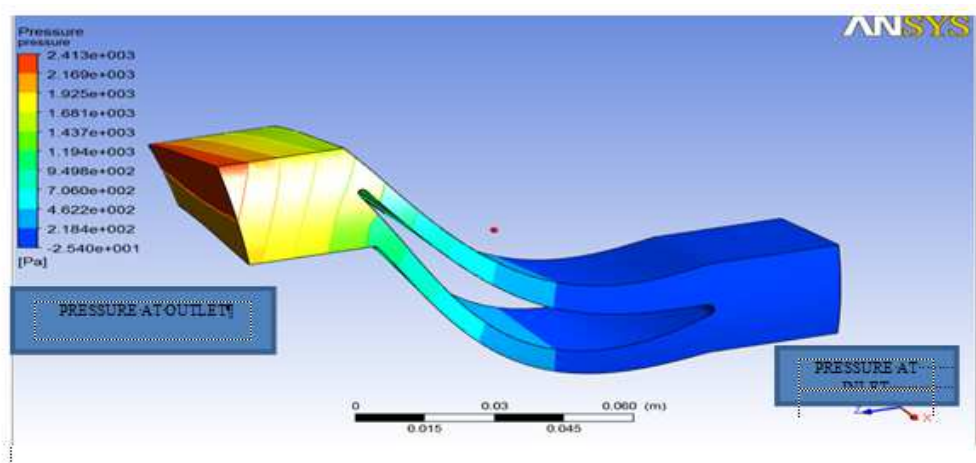


Figure 8: Pressure at Inlet and Outlet

The outlet pressure was found to be 2413 Pa.

MACHINE DRAWINGS

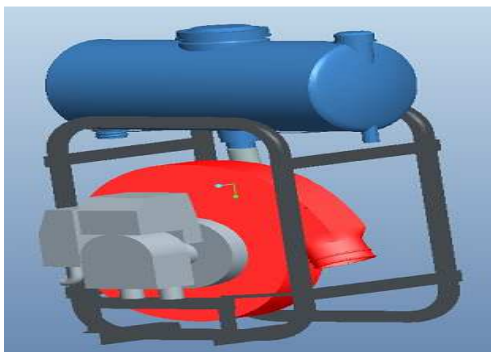


Figure 9: Cad Model



Figure 10: Fabricated Machine

RESULTS

Field trial has been carried out, considering the following parameters.

Table 2: Field Trial Details

Hour	Manual Picking Kg/Hr	Cumulative Picking (Kg)	Machine Picking Kg/Hr	Cumulative Picking (Kg)
1	9	9	10	10
2	9	18	10	20
3	8	26	10	30
4	8	34	10	40
5	7	43	10	50
6	7	50	10	60
7	6	56	10	70
8	6	62	10	80

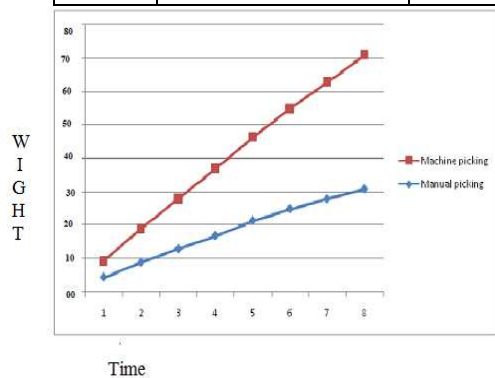


Figure 11: Manual Picking and Machine Picking Graph



Figure 12: Researcher Picking Cotton Boll Using Machine

The calculated velocity and pressure values, at the outlet of impeller are found to be 66.45 m/s and 2612.41 Pa, and by using CFD analysis, these are 64.50 m/s and 2413Pa, respectively. From figure 11, it can be concluded that, the use of proposed machine improves picking capacity of the user.

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